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Control of the "Greyback" Cane Grub Pest, *Dermolepida albohirtum* Waterh., by Means of "Gammexane" (Benzene Hexachloride)*

By R. W. MUNGOMERY, Officer in Charge, Entomology and Pathology, Bureau of Sugar Experiment Stations, Division of Plant Industry.

SUMMARY

Following the initial successful testing of "Gammexane" against cane grubs in Queensland in 1945, experimental work was undertaken to determine the effect of seasonal and soil conditions and time and method of application on the efficacy of the treatment, the minimum effective dose, and the phytotoxicity of the material.

No toxic effects on sugar cane or Poona cowpea were observed with applications of normal amounts of "Gammexane." There was slight stunting of plant cane with an application of 1,000 lb. of 10% dust per acre, but 600 lb. produced no deleterious effect on ratoon cane.

Band application of various amounts is more effective than the broadcasting of corresponding quantities.

Satisfactory control of grubs is secured if application of "Gammexane" is made prior to or during beetle flight.

A dressing of 100 lb. of 10% dust to either a plant or a ratoon crop provides adequate control of infestations. A lower amount may prove satisfactory for moderate infestations on heavier soil types, but at least 75 lb. should be applied.

Where the amount of "Gammexane" applied is sufficient for only one crop, or where ratooning operations involve removal of the insecticide from the vicinity of the stools, a "booster" treatment of 50 lb. after ratooning is effective in restoring the efficacy of an original dressing of less than 100 lb.

The single treatment for either a plant or a ratoon crop, or the practice of making an initial and a "booster" application, may profitably be replaced by a single application to the plant crop of 150 lb. of 10% dust, which provides protection for the plant and two ratoon crops. The amount may be reduced to 125 lb. where only one ratoon crop is harvested.

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* The benzene hexachloride preparation bearing the trade name "Gammexane" was the only BHC product available to Queensland canegrowers until the middle of 1949. As all the results recorded in this paper were secured with this product and as it is common usage to refer to BHC as "Gammexane" in the Queensland sugar industry, the name is used throughout the paper.

INTRODUCTION

The history of cane growing in Queensland contains many accounts of extensive crop destruction in certain districts due to the depredations of " white grubs." These are the larvae of several native Scarabaeid beetles, but the species responsible for the greatest crop losses from Mackay northwards is the " greyback " cockchafer, *Dermolepida albohirtum* Waterh., undoubtedly one of the worst pests with which any cane-growing country has had to contend. The occurrence, life-history, habits, parasite complex and economic importance of this insect were investigated more or less concurrently by Illingsworth and Dodd (1921) and Jarvis (1927). Later workers devoted their efforts to improving methods of control, and the approach was made along both biological and chemical lines. So that the problems associated with the control of this pest may be appreciated, its life history and habits will be briefly described, and some of the measures that were previously employed in attempts to restrict its activities will be outlined before proceeding to a discussion of control by means of " Gammexane."

LIFE HISTORY AND HABITS OF THE " GREYBACK " BEETLE

The beetles are usually first seen on the wing at dusk, generally between October and December, but sometimes into January. Their emergence during this period is governed chiefly by the occurrence of a substantial fall of rain (usually at least two inches), sufficient to moisten the soil and allow them to burrow upwards to the surface. On emergence, they fly to adjacent rain forest or eucalypt forest, where they feed on eucalypts, figs, palms, etc., and where mating takes place. After a period of about two weeks, a flight is made to the canefields, where the beetles re-enter the soil and deposit their eggs at depths of nine to 18 inches, each female laying approximately 28 eggs. Under ordinary moist soil conditions, incubation proceeds normally and within two weeks the small grubs are hatched. There are three grub stages, all of which are similar in appearance though differing greatly in size. The first stage lasts for approximately one month, the second for five weeks, and the third for six or seven months. The last two or three months of the third larval period are spent in a more or less inactive pre-pupal condition, after the large third-stage grubs have fed voraciously for three or four months on cane roots and on the underground portion of the stalks. When fully grown, they measure slightly more than two inches in length on being fully extended and about $\frac{3}{8}$ inch in thickness. Pupation takes place about September in earthen cells at an average depth of 14 inches, and in these the pupae eventually transform to beetles a month later. Thus, the entire cycle occupies a period of about one year.

Though the beetles have sometimes been known to feed on cane leaves for a limited period, it is the larval stage that is solely responsible for the serious damage inflicted on cane crops. The newly hatched grubs ingest quantities of soil and in the early period of their development derive a considerable amount of nourishment from the organic matter contained therein. As they gradually work their way upwards, they contact the cane roots near the surface and commence to feed on them. There they continue to feed so long as weather conditions remain favourable, but, should the surface soil dry out, they burrow more deeply and feed where there

is adequate moisture. They follow the cane roots towards the rows, and by the time they have entered the second and third larval stages most of the grubs have concentrated around the base of the stools. This concentration usually occurs in February or March, and from then until May or June the grubs become increasingly destructive. Grub-infested cane first looks as though affected by drought, with an initial yellowing of the leaves and drooping of the inner spindle ; later there is death of the leaves and consequent deterioration of the maturing stalks. In extreme

Figure 1.
A crop of plant cane in the Mulgrave area showing extensive damage and uprooting of stools due to grubs.

cases the whole stool is deprived of its roots, loses its anchorage and is readily levered out of the ground by its own weight (Figs. 1 and 2). On dry red-soil areas one grub per stool is sufficient to inflict serious damage ; on some rich alluvial soils, three or four grubs can be present under a stool of cane without causing any obvious ill-effects. During periods of heavy infestations, grub populations of between 10 and 20 per stool are commonly encountered.

AREAS LIABLE TO INFESTATION

Infestations within a particular district usually coincide broadly with areas damaged in earlier outbreak years, and in these areas the more advanced crops with dense foliage usually become the more heavily infested. It is possible, therefore, to forecast pest incidence with a reasonable degree of accuracy providing certain other factors are taken into consideration. These include the possibility of dry conditions occurring during the critical period between beetle emergence and hatching of the eggs, when loss of soil moisture may reduce pest populations to harmless levels. In the wetter areas such dry periods are unlikely and cannot be relied on to affect the pest appreciably.

Figure 2.

A crop of ratoon cane in the Mulgrave area that was flattened and destroyed by grub attack. (The cane in the foreground was cut and used as planting material in an attempt to recoup some of the loss.)

Information concerning farms likely to become infested has been obtained in surveys of grub damage conducted annually since 1934 in cane areas from Tully to Cairns. As a result of these surveys a clear picture has been secured of the areas liable to damage as well as those uninfested, and they have been classified into the following four categories :—

(a) Areas in which no infestations have been recorded.

(b) Lightly infested areas showing no appreciable damage.

(c) Moderately infested areas showing some damage but no appreciable uprooting of stools.

(d) Heavily infested areas showing severe damage and considerable uprooting of stools necessitating a plough-out.

On the accompanying map have been plotted the location of possible centres of grub infestation and the severest degree of damage encountered on each individual farm in the Mulgrave and Babinda mill areas. The former area has suffered severe grub infestations on many occasions, while the latter usually suffers very little damage. Similar details are available concerning areas liable to infestation in other mill areas and, having due regard to these and to the information available regarding local beetle and grub populations, growers can be advised whether or not their fields are likely to become grub-infested. The anticipation of infestation, therefore, was the essential background in some of the investigations subsequently undertaken with "Gammexane."

EARLY CONTROL MEASURES

In early attempts to control the pest, payments were made for the collection of grubs and beetles in many districts, but effective results were not obtained. Late planting allowed some fields to escape infestation, but the lower yield obtained did not render this practice attractive. The use of varieties capable of regenerating their roots rapidly has been advocated as a means of lessening the impact of grub attack but, where dense populations are involved, the limits of varietal resistance are often exceeded and the crop collapses. In the past, some fertile cane properties were allowed to revert to forest or to grass simply because successive infestations had been so consistently heavy that cane could not be grown there without considerable expenditure on control measures. Though for a number of years soil fumigation with carbon bisulphide had proved the most satisfactory method of control, various mixtures of this chemical with the dichlorbenzenes were introduced in an attempt to improve results under adverse soil conditions. Knust (1934) described the work entailed in a soil-fumigation campaign in North Queensland, pointing out that the operation needed constant supervision. It was never a popular undertaking and soil fumigation made little headway (Table 1), for even during

Table 1

SHOWING ACRES FUMIGATED, ACRES DAMAGED, AND TONS OF CANE DESTROYED IN THE AREA FROM TULLY TO CAIRNS, 1940-1948.

Year	Acres Fumigated	Acres Damaged	Est. Loss in Tons of Cane
1940	1,900	Not available	Not available
1941	1,570	4,000	,, ,,
1942	870	5,370	,, ,,
1943	840	9,140	67,000
1944	1,183	5,000	30,000
1945	900	4,900	32,000
1946	1,514	13,000	105,000
1947	434*	2,090	7,250
1948	137*	4,500	14,000

* "Gammexane" was supplanting carbon bisulphide during these years.

1946, a year of heavy infestations, only a little over 1,500 acres were fumigated in the far north of Queensland out of a total of 13,000 acres damaged, entailing a loss of approximately 105,000 tons of cane. Even in the pre-war years when there was no labour shortage the area fumigated never exceeded 2,000 acres in any one year.

The main factors militating against the widespread use of carbon bisulphide for grub control in Queensland canefields were as follows :—

(a) Cost of treatment with this fumigant is relatively high. In pre-war years costs were seldom below £8 an acre and they frequently exceeded £10.

(b) The risk of explosion of the chemical entailed special precautions during transport, storage and use.

(c) Its high volatility limited the duration and range of its killing effects after injection into the soil. Hence, it was of little value where two or more successive beetle flights were involved.

(d) Successful control when soil conditions were below optimum—i.e., too wet or too dry—was uncertain.

(e) The work had to be carried out during periodical breaks of fine weather between monsoonal downpours.

(f) It was difficult to attract and keep suitable labour for this class of work, which is unpleasant in nature.

(g) The work is slow and there is a risk of damage occurring before its completion. Normally one man is capable of fumigating about half an acre a day.

Because of these drawbacks, soil fumigation had little appeal to growers, field workers or supervisors of Cane Pest and Disease Control Boards, the three parties most interested in pest suppression.

Various materials were tested over a period of years as alternatives to carbon bisulphide, but until the advent of the benzene hexachloride preparation marketed as " Gammexane " none proved satisfactory.

EXPERIMENTS WITH " GAMMEXANE "

In the initial test of " Gammexane " against cane grubs (Mungomery, 1945), complete control was obtained in plots treated at the rate of 100 lb. of 10% dust (1.3% gamma isomer) per acre. This test was so outstanding that provisional recommendations were made to enable growers to take full advantage of it right from the outset, and field experimental work then proceeded concurrently with farmer usage of the insecticide. Cane Pest and Disease Control Boards co-operated with the Bureau by arranging with farmers to leave untreated strips in their treated fields so that additional data could be secured.

The series of trials initiated by the Bureau in 1946 were designed to determine (a) the validity of the preliminary results under various weather and soil conditions ; (b) the effect of varying times and methods of application of the dust ;

(c) the minimum effective dose ; and (d) phytotoxicity to the cane crop and to legume crops in the rotation.

Since only a small quantity of "Gammexane" dust was available for experimental purposes in 1946, trials were largely of an exploratory nature. These trials contained a series of single treatment plots, each three rows wide by one chain long, interspersed with suitable checks. They were placed on a number of different soil types and in districts with different weather conditions.

Some of the exploratory trials were deliberately set out in areas that were unlikely to become grub infested, so that any toxic action which "Gammexane" might have on the cane plant could be readily evaluated.

In other cases, where grub infestation was a distinct possibility, they were set out as early as August in order that the young cane would be growing in proximity to the insecticide for at least six months before any serious grub infestation could develop ; it was considered that any phytotoxic effect which the insecticide might produce should begin to be apparent before then. Thereafter, the treatments were to be used as an indication of the dosage requirements for grub control. The rates of application used in these exploratory trials were 12½, 25, 50, 75, 100, 125, 150, 200 and 400 lb. of 10% "Gammexane" dust (1.3% gamma isomer) per acre. During 1946 and 1947 a limited number of Latin square and randomised block trials, with plots of 1/20th acre, were put down in an attempt to secure more reliable statistical data. Rates of application in these latter trials varied between 50 and 400 lb. of 10% dust per acre.

In all, 64 trials were established in 1946 and 1947, 10 being replicated plot trials and the remainder exploratory. Their distribution in the various cane-growing districts liable to grub infestation was as follows :—Mossman, 7 ; Cairns-Gordonvale, 30 ; Babinda, 6 ; Innisfail-Tully, 16 ; Burdekin, 5.

Grub infestation following the 1946 and 1947 beetle flights was generally light, and many plots failed to yield useful information because of lack of infestation or very light infestation. A few, however, became moderately infested and results from them formed the basis of further experimental work. During 1948 and 1949 there was a substantial upsurge in pest populations, and a summary of the information secured in those years is given in the following sections.

Phytotoxicity

In a series of tests carried out at the Northern Sugar Experiment Station, Gordonvale (Buzacott, 1948), "Gammexane" intimately mixed with soil caused no observable effect on the development of the shoot buds on cane setts germinating therein, but there was an inhibition of both primary and secondary root development. On the other hand, when the insecticide was applied in the field to the soil surface along the rows of germinated cane and worked in with the usual cultivating implements, no effect on growth was apparent, even when the crude benzene hexachloride was used at the rate of 60 lb. per acre. Laboratory trials with each of the pure alpha, beta, gamma and delta isomers indicated that the gamma isomer was the least phytotoxic. McDougall (1948) in work on control of the wireworm

Lacon variabilis also noted stunting of primary roots developing from the cane sett under some conditions where they contacted the insecticide. For that reason, in his earlier recommendations for the control of these pests, he advocated that the " Gammexane "-fertilizer mixture (20 lb. of 10% " Gammexane " dust + 3 cwt. fertilizer per acre) should be applied in the drill at planting time in such a manner that it would fall just above but not in direct contact with the setts. In later experiments (McDougall, 1949), he demonstrated that even if the " Gammexane "-fertilizer mixture came in partial contact with the setts there was no significant depressing effect on ultimate yields.

Hughes (1949) reported that he had cultured soil bacteria and fungi on nutrient agar in the presence of " Gammexane " and growth of the soil organisms had not been inhibited unless in actual contact with the insecticide. However, he concluded that at normal dosage rates " Gammexane " would have practically no effect on the soil micro-flora.

In the field trials, satisfactory germination and growth were secured where " Gammexane " was applied at the rate of 150 lb. of 10% dust per acre as a broadcast dressing, and at 100 lb. per acre in the drills prior to planting.

In one field experiment in which " Gammexane " was broadcast at the rate of 1,000 lb. of 10% dust per acre and later worked into the soil, there was a slight stunting effect in the early stages of the cane's growth, but later this effect became barely discernible. Plants of Poona pea (*Vigna unguiculata*), which is frequently grown as a green manure crop following cane, showed no adverse effects when grown under high concentrations of this insecticide.

In ratoon cane which was treated at rates of up to 600 lb. of 10% dust per acre by opening up furrows on each side of the cane row and applying the dust in them, there was an excellent development of roots, and the stools became so well anchored that they were difficult to remove when an examination of the root system was subsequently made. Not even the heaviest application caused damage to the resulting crop in this case.

There were many field trials involving applications as high as 400 lb. of 10% dust per acre, either as band dressings to the drills or as broadcast dressings disced in or ploughed under, and in none of these was any phytotoxic effect noticeable. On the other hand, even in the absence of grubs in both treated and control plots, some of those at the higher treatment levels often showed slightly better growth and a darker green foliage. This phenomenon was not due to some fertilizer value possessed by the insecticide, for in a replicated trial in the Innisfail area (Table 2),

Table 2

Summary of Yields of Cane in Toxicity Tests in the Absence of Grub Infestation.

Treatments	" Gammexane " 10% dust, per acre			CS_2 app 200 lb per ac.	Check
	100 lb.	150 lb.	200 lb.		
Cane, tons per acre	26.66	24.82	25.74	25.13	24.65
Percentage mean yield ...	105.0	97.7	101.3	99.0	97.1

which failed to become grub infested, the various treatments had no effect on yields. The farm selected for this trial normally showed a response to a complete fertilizer mixture.

The required difference for significance at the 5% level was 3.00 tons, so it is obvious that the "Gammexane" dressings produced neither a depressing nor a beneficial effect on crop growth.

Many of the treatment levels cited in the various experiments were considerably in excess of the minimum required for effective grub control under the most exacting conditions and, since no phytotoxic effects were noticed except at the highest level tested (and then they were only slight), it seems safe to conclude that no adverse effects are likely to follow normal applications of this insecticide to cane lands for grub control.

Method of Application

Band versus Drill.

The earliest field trial with "Gammexane" against cane grubs was conducted by applying the insecticidal dust to the plant cane as a band some 15-18 inches wide along the drill after the cane had germinated and become well established. By the time the field had finally been worked level with cultivating implements the insecticide was well incorporated in the soil around the base of the cane stools. Using a dosage rate of 100 lb. of 10% dust per acre, a mortality of 85% was recorded while the grubs were still in the first larval stage, and practically 100% kill was secured before they had reached the late second stage. From this it will be evident that, as grub attack developed and the young grubs moved in laterally towards the cane rows, they contacted the "Gammexane"-contaminated soil near the base of the cane stools and quickly succumbed. Thus complete control was effected before it was possible for the grubs to inflict any appreciable damage on the cane stools.

This band method of application is the one most commonly used at the present time, but a slight modification is necessary when treating ratoon crops. In this case it is customary to open up a furrow on each side of the cane rows with either a plough or some other ratooning implement, the dust being distributed in the furrows so formed. These furrows are then filled in either with grubbers or by "bursting" the centres of the interspaces.

Though the band method of application was found to be efficacious, it was thought desirable to test various broadcast methods, particularly since Buzacott, in an unpublished report, had stated that a concentration of one part per million of the gamma isomer in soil was sufficient to cause death of half the beetles within three days. Consequently, the idea of blanketing whole fields with "Gammexane" in an attempt to intercept beetles as they emerged, or as they returned to the fields to oviposit, was developed. Moreover, in the case of beetles that might evade the poison and succeed in laying, there was the added possibility that the small grubs would die before they could develop any degree of resistance to the insecticide. Accordingly a number of broadcast dressings were made in which the insecticide was spread over the entire drills and interspaces after the cane had germinated.

Cultivating implements later mixed the insecticide with the surface soil. In other instances, after being broadcast, the " Gammexane " dust was ploughed under or disced in before the fields were planted.

There was nothing to show that one method of broadcasting was superior to another, and though all exercised some measure of control the results were inferior to those produced by the same amount of insecticide applied to the cane rows as a band dressing. In one trial a 100 lb. broadcast treatment was only as effective as a 50 lb. band treatment. In another trial a 300 lb. broadcast treatment gave the same measure of control as a 100 lb. band treatment. In still another, which became lightly infested, a broadcast dressing of 100 lb. per acre permitted general light damage over the entire plot, whereas a band dressing of 100 lb. per acre, properly applied, has not been known to fail in affording a crop of plant cane complete protection against even the heaviest infestations. Hence, broadcast dressings are obviously uneconomical to use for this purpose, since they require some two or three times the quantity of insecticide to effect the same degree of grub control as that achieved with band dressings.

Machinery.

" Gammexane " applications were at first made either by hand or from a tin having a perforated bottom and attached to a handle about four feet long and an inch in diameter. In the latter case the tin was held over the cane rows as the operator walked along, and the insecticide was distributed evenly by tapping the handle. Upwards of five acres per man per day were treated in this manner.

Farmers were encouraged to adapt existing machines to their requirements, and Wilson (1948) described a number of fertilizer distributors which, with minor alterations, were found satisfactory for applying " Gammexane " as a band dressing.

Some of the alterations suggested involved an extension of the chutes so that the dust would be delivered right on the surface of the cane drill with a minimum of disturbance by wind. The tynes were so adjusted that they served to incorporate the " Gammexane " in the soil and at the same time destroyed any small weeds in the rows. Thus routine cultivation work and the application of the insecticide were carried out simultaneously. In addition, special provision was made to prevent the implements from moving sideways on hillsides and distributing the " Gammexane " outside the cane rows.

Humphry (1948) also described and illustrated a method whereby a standard fertilizer box was attached to the front cultivator bar of a high clearance tractor and distribution of the " Gammexane " was effected by a sprocket-and-chain driven mechanism operated from the back axle. This unit was capable of treating 20 acres per day.

Despite the improvisations made, it was soon found that the number of machines in some mill areas was too small to cope with all the fields that needed treating, and consequently other machines were developed expressly for the application of " Gammexane." For the most part they resembled in operation a narrow lime spreader, and about 10 acres per day could be treated.

Some of the earlier machines tended to apply the dust thinly over too wide an area, and in some extreme cases virtually the whole of the interspace was covered while a large portion of the drill was left untreated. Growers then had to rely on their subsequent cultivation operations to transfer the insecticide into the cane rows. This was seldom possible. Most of the few reported failures in grub control have been traced to application of the insecticide in the interspace with no subsequent movement of the treated soil into the cane rows.

These faults were subsequently corrected, and later modifications to these machines, which involved blocking up some of the outer delivery holes and narrowing the chutes, resulted in a marked improvement in the placement of the dust, while some of the newer machines aimed at applying the dust in a more concentrated band in the drill.

Time of Application

In the initial trial with "Gammexane" the forecast regarding infestation was accurate, and heavy oviposition occurred in the trial area some five to six weeks after the dust had been applied to the cane rows. Successful control of the resulting grubs was subsequently obtained. Some growers, however, are reluctant to institute control measures until the pest is actually established in the fields. Hence, several trials were set out to determine the latest period at which "Gammexane" could be applied for successful control. Treatments involving various dosage levels were applied as follows:—

(a) One to two months before beetle flight.

(b) During beetle flight.

(c) One month after beetle flight.

(d) Two months after beetle flight.

(e) Three months after beetle flight.

Results showed that satisfactory control was secured if applications were made at any time prior to or during beetle flight. There was some control when the dust was applied a month after beetle flight, but at normal treatment levels the damage subsequently inflicted by grubs was sufficiently severe to render it risky. Proportionately lower control was effected by later applications, and in an application made two months after beetle flight there was damage in all treatments up to and including the 200 lb. per acre band dressing. When the treatments were made three months after beetle flight, damage was severe at the 200 lb. rate and was also apparent at the 400 lb. rate. Since grub surveys do not usually give a reliable picture of infestation before two months after beetle flight, "Gammexane" applications made immediately afterwards on the basis of this information would at best yield poor control at the higher treatment levels, while later applications would prove virtually useless. In addition, there are various practical considerations which militate against success with these late applications. In the first place, a factor to be reckoned with is the height of the cane at the time when these late dressings would have to be applied. Not only would a considerable number of stalks be snapped off as the distributing implements passed either over the rows or along the interspaces, but the breadth of the stool would also render difficult the

application of the dust in or near the cane rows and its admixture with the soil near the stools. In addition, heavy monsoonal downpours are normal at that time of the year and would be expected to prevent the working of implements on the land. If recourse were made to hand application, the difficulty of incorporating the dust in a thoroughly saturated soil would still present a problem.

From a consideration of the foregoing, it is evident that for maximum benefit " Gammexane " must be applied before or during beetle flight, but considerable latitude is allowable and the question of arriving at the optimum time for application becomes a matter of determining the most suitable time to fit this control work in with ordinary routine cultivation. Normally, the cane rows are kept open until the cane is adequately stooled and then filled in gradually until the land is restored to a level state by the time the cane is " out of hand." Therefore, if " Gammexane " is applied just before the soil is worked back, it will remain in the rows and become intimately mixed by subsequent tillage operations, thus fulfilling the basic requirement regarding placement. Hence, the time to apply " Gammexane " depends primarily on the stage of development of the crop and this in turn depends on the time of planting and the conditions for subsequent growth. However, in most instances plant crops will be ready to receive their treatment between August and November ; ratoon crops obviously would require treatment at the time of ratooning.

Rates of Application

Since a dressing of 100 lb. of " Gammexane " per acre had proved satisfactory in the initial test, in subsequent trials the rate of application ranged from 100 lb. down to 12½ lb. per acre, though heavier dressings were tested on other soil types.

An application at the rate of 25 lb. per acre gave inadequate control for practical purposes, but the 50 lb. treatment appeared satisfactory in dealing with light infestations on heavy soil. The latter rate, however, was unable to cope with light infestations on friable soils or with moderate infestations on medium to heavy soils, where in one instance up to four grubs per stool were involved. In these plots there were unmistakable signs of grub attack, such as yellowing of the foliage, root pruning, and some destruction of the basal portion of the stool. Since the precautionary measure of applying " Gammexane " for grub control would imply an expectation of at least light infestations on friable soils or moderate infestations on heavier soils, the 50 lb. dressing is considered too low for the first application to either plant or ratoon cane.

A dressing of 75 lb. per acre proved adequate in dealing with light to moderate infestations in either plant or ratoon cane, but it proved insufficient to prevent damage showing up in some plant crops in which heavy infestations (from five to 18, with an average of approximately 12, grubs per stool), were involved. There was also evidence to show that it was less satisfactory than the 100 lb. treatment on a block of ratoon cane growing on friable red soil in the South Johnstone area. In general, it appears that 75 lb. per acre is the lowest amount that should be applied for a single crop treatment of plant or ratoon cane (*see* Fig. 3 for an illustration of the value of an 84 lb. dressing), and even then it should be restricted to the heavier soils. When assessing the value of various treatments for crop protection,

Figure 3.

A crop of plant Trojan cane showing the effect of an application of 84 lb. 10% "Gammexane" dust per acre. Cane on right treated; cane on left untreated.

Figure 4.

A crop of ratoon cane showing the effect of an application of 84 lb. 10% "Gammexane" dust per acre to the plant crop. Cane on right treated; cane on left untreated.

Table 3

RESULTS OF BADILA PLANT CROPS HARVESTED FROM TWO 12 × 4 RANDOMISED "GAMMEXANE" 3-YEAR PERSISTENCE TRIALS.

Treatment rates in lb. per acre	No. of Plots	FARM D.—Clayey Schist Soil. "Gammexane" applied 19/10/48. Plant crop harvested 17/8/49. Average grub population per untreated stool=6.4		FARM P.—Grey Schist Soil. "Gammexane" applied 27/10/48. Plant crop harvested 5/7/49. Average grub population per untreated stool=12.	
		Mean Yields in tons per acre	Remarks	Mean Yields in tons per acre	Remarks
0	4	22.74	Cane showed obvious signs of extensive grub damage.	22.42	Cane lodged and uprooted in all plots. Considerable grub damage.
200 lb. carbon bisulphide.	4	23.81	Cane showed evidence of earlier grub attack. Fumigated 28/4/49. Grub mortality 85%.	24.34	Cane lodged and damaged. Fumigated 9/5/49. Grub mortality 64%.
75 lb. 10% "Gammexane"	16	29.54	No visible grub damage.	31.66	Slight grub damage apparent by wilting and yellowing of foliage.
100 lb. 10% "Gammexane"	12	30.3	No visible grub damage.	32.11	No visible grub damage.
125 lb. 10% "Gammexane"	8	30.14	No visible grub damage.	30.08	No visible grub damage.
150 lb. 10% "Gammexane"	4	28.45	No visible grub damage.	30.83	No visible grub damage.

In the above trials the 75, 100 and 125 lb. treatments with 10% "Gammexane" dust on Farms D and P and the 150 lb. treatment on Farm P all exceed the carbon bisulphide and nil treatments at the 1% level of significance, while the 150 lb. treatment on Farm D exceeds the carbon bisulphide and nil treatments at the 5% level of significance. Other differences are not significant.

yield differences should not always be accepted as the final criterion. Grub damaged blocks are usually harvested soon after the commencement of crushing operations and before any considerable crop deterioration has occurred, hence damage which is not always apparent in yield may often be reflected in decreased vigour in the following ratoon crop (*see* Fig. 4).

A 100 lb. dressing, properly applied, controlled the heaviest infestations in plant and ratoon crops under all conditions even when populations approached 20 per stool. This, then, has been fixed as the standard treatment where a single crop needs protection against heavy infestation.

Table 3 shows yields of the plant crops from the randomised "Gammexane"-persistence trials which were established in 1948. As originally planned, these trials included various combinations of treatments divided between the young plant cane and first ratoons for comparison with equivalent amounts applied as single dressings to the plant cane. So far, only the plant crops have been harvested; however, the degree of control achieved with the 75 lb. and 100 lb. treatments is of interest, and the results substantially confirm the conclusions outlined above.

On farm D the 75 lb. rate of treatment sufficed to control the moderate infestation on the heavier soil there, since there was no evidence of grub damage developing in those plots. On the other hand, farm P suffered a very heavy infestation of grubs and, although in this instance the 75 lb. treatment showed no loss in tonnage when compared with the higher rates of treatment, there was a definite wilting and yellowing of the foliage through grub attack. This indicated that control had not been complete and the vigour of the subsequent ratoons could have been adversely affected. Plots treated at rates of 100 lb. per acre and over showed no signs of grub damage.

The carbon bisulphide treatments, because of unfavourable weather conditions, had to be delayed until April 28 and May 9, 1949, respectively, and even then only 64 per cent. mortality was obtained on Farm P. In those circumstances it was inevitable that considerable grub damage would develop, a typical happening in previous years during any normal fumigation campaign. The carbon bisulphide plots averaged one to two tons per acre more than the untreated plots, but the differences are not significant, and the chief gain in these cases would have been in saving the stools for the ratoon crops. On the other hand, the results demonstrated very forcibly the superiority of the "Gammexane" treatments, which gave a highly significant increase of seven to eight tons per acre over the check plots.

Re-treatment of Ratoons

In the original field experiment "Gammexane" remained toxic for five or six months, and it was reasonable to expect that it might retain some of its toxicity into the following ratoon crop. Accordingly, in further trials, after the plant crops had been harvested and the blocks ratooned, a "booster" treatment was applied as side dressings to furrows made alongside the rows of all plots except those which had received over 200 lb. per acre, in an attempt to restore an effective level of toxicity. The rate for re-treatment was fixed at 50 lb. per acre, as any quantity substantially below this figure would have involved difficulties in application.

Results from these re-treatments showed that, where a light to moderate infestation was involved in the friable red volcanic soils at South Johnstone, there was a definite response to a " booster " dressing of 50 lb. per acre in the case of original treatments of 50 lb. and 75 lb. per acre, but original treatments of 100 lb. and over showed no benefit from this re-treatment. In a heavy infestation on medium soil in the Mulgrave area, a treatment of 40 lb. per acre to the first ratoons gave a substantial improvement where a grower had applied to the plant crop a dressing at the rate of 92 lb. per acre (*see* Fig. 5).

Figure 5.

A crop of ratoon cane showing the effect of a " booster " application of "Gammexane " to the ratoon crop. The whole block was treated in October, 1947, at the rate of 92 lb. 10% "Gammexane " dust per acre. The cane on the left was given a " booster " treatment at the rate of 40 lb. per acre in November, 1948, and was undamaged. The cane on the right received no additional treatment and showed moderate grub damage. The photograph was taken in July, 1949.

This method may be quite important in the Burdekin area. There, during ratooning operations, it is customary to slice away a considerable portion on each side of the stool, and this is turned over into the interspace. By adopting this method of ratooning a considerable proportion of the original " Gammexane " dressing may be carried over with the soil adhering to the sliced portions of the stool, and this is never replaced in exactly the same relative position. Consequently, the continuity of the " Gammexane " barrier may be destroyed, but it could be restored by re-treatment as outlined above.

Residual Toxicity Without Re-treatment

In the original approach to the problem of grub control with "Gammexane," the emphasis was mainly on the minimum dressing necessary for effective protection of one crop, for it was scarcely conceived at that time that this material, when placed in the soil, would remain toxic over a period of some years. The early experiments were accordingly designed to give information on minimum dressings. However, in view of the fact that the insecticide remained toxic for a number of months it was decided that some plots or portions of plots should not be re-treated, in order to ascertain just how long different concentrations would remain effective.

Table 4

DATA AND OBSERVATIONS FROM EXPLORATORY TRIALS IN THE MULGRAVE AREA, SHOWING PERSISTENCE OF TOXIC EFFECT OF "GAMMEXANE" INTO THE RATOONS FOLLOWING SINGLE DRESSINGS TO PLANT CROPS OF BADILA.

Treatment rates in lb. 10% "Gammexane" dust per acre applied as band dressings along cane rows	Results in 1st ratoon crop on Farm A. Treated 21/11/46. Very heavy grub infestation in 1948			Remarks on second ratoon crop on Farm B. Treated Nov. 28, 1946. Very heavy grub infestation in 1949. Harvested June 14, 1949, but no records of plot weights secured†
	Mean Grub population per stool at May 18, 1948	Yields in tons per acre, June, 1948	Remarks*	
Nil (av. 4 plots)	11.0	21.4	Cane tops dying and ready to break off.	Cane severely damaged and pinched off in all plots, uprooted and foliage dying.
12½	12.0	20.6	Almost no grub control.	No apparent control.
25	8.0	20.5	Very little grub control.	No apparent control.
50	4.5	27.3	Substantial grub damage but better than 25 lb. treatment.	Slightly better than check plots but considerably damaged.
75	1.5	27.6	Noticeable grub control.	Slightly better than check plots but considerably damaged.
100	.5	26.7	Very slight grub damage.	Foliage losing green colour and some damage noticeable. Considerable loss in growth compared with 150 and 200 lb. treatments.
125	.5	29.0	No obvious signs of grub damage.	Foliage losing green colour and some damage noticeable. Cane growth satisfactory but less cane than 150 lb. treatment.
150	1.0	27.3	No obvious signs of grub damage.	Foliage green; cane growth good; no apparent grub damage.
200	.5	32.1	No obvious signs of grub damage.	ditto.

* When sampled for analyses in June, 1948, some sticks in the samples from damaged plots on Farm A had pinkish-red areas (red rot) developing in the internodes.

† When diggings were made on 1/6/49, it was evident from the number of bandicoot holes in different plots that many grubs had been destroyed by these animals. However, bandicoots had not apparently interfered with the 150 lb. and 200 lb. plots, which showed an average of 4.25 and 4.5 grubs respectively per stool. The check adjacent to the 150 lb. treatment showed an average of 12.25 grubs per stool even after having been raided by bandicoots.

Figure 6.
A second ratoon crop of Badila cane showing the effect of the residual toxicity of "Gammexane" to grubs. The cane on the right was treated in the plant crop in November, 1946, at the rate of 200 lb. 10% "Gammexane" dust per acre. The cane on the left was untreated. The photograph was taken in July, 1949. (See last column of Table 4 for further information.)

Figure 7.
A second ratoon crop of Cato cane showing the effect of the residual toxicity of "Gammexane" to grubs. The cane on the left was treated in the plant crop in November, 1946, at the rate of 150 lb. 10% "Gammexane" dust per acre. The cane on the right was untreated. The photograph was taken in July, 1949. (See Table 5 for further information.)

Table 5

SUMMARY OF YIELDS AND OBSERVATIONS IN A LATIN SQUARE TRIAL ON FARM C, MULGRAVE AREA, SHOWING RESIDUAL TOXICITY OF "GAMMEXANE" IN RATOON CROPS OF CATO AFTER SINGLE DRESSINGS TO THE PLANT CANE.

PLANTED MAY, 1946, ON BROWN SCHIST SOIL. TREATMENTS APPLIED 12/11/46.

Date of Harvesting	Yield in tons per acre at treatment rates indicated in lb. of 10% "Gammexane" dust per acre				Remarks
	nil	100 lb.	150 lb.	200 lb.	
12/11/47	27.04	28.09	28.83	28.82	Light grub infestation, approx. 1 per stool in controls; 200 and 150 lb. treatments exceed check at the 1% level.
16/8/48	27.51	34.13	35.78	34.90	Heavy infestation. Considerable damage visible in controls and slight damage in 100 lb. treatment. None in 200 and 150 lb. treatments; 200, 150 and 100 lb. treatments exceed check at the 1% level.
29/6/49	10.18 (8.2)*	17.71 (4.9)	20.1 (3.4)	20.71 (2.6)	Very heavy infestation. Heavy damage in control plots and considerable damage visible in 100 lb. treatments. No damage visible in 200 and 150 lb. treatments; 200 lb. and 150 lb. treatments exceed 100 lb. treatment and check at the 1% level; 100 lb. treatment exceeds check at the 1% level.
Totals for 3 crops ...	64.73	79.93	84.71	84.43	

* Early diggings in 1949 showed high grub populations averaging approximately 15 per stool, but when subsequently dug on 25/5/49 average grubs remaining per stool in different treatments were then as shown in brackets.

In 1948 a series of first ratoon plots which had been treated as plant cane in November, 1946 became heavily infested. So badly was the crop damaged outside the boundaries of the plots that the grower decided to plough the block out. Hence, in this instance, though data were secured from the first ratoon, no information was available regarding possible carry-over effects into the second ratoon crop. However, another block that was treated in 1946, and which virtually escaped infestation in 1947 and 1948, became heavily infested in 1949—i.e., in the second ratoon crop. Results of these two exploratory trials and a Latin square trial were so striking that full details are presented in Tables 4 and 5. The effect on two of the farms is illustrated in Figures 6 and 7.

Ratooning operations in the above experiments were carried out with grubbers or similar implements, the use of which involved no great movement of the soil away from the cane rows; thus the "Gammexane" remained practically *in situ* throughout the entire period occupied by the three crops. The one-treatment schedule, then, should be applied only under these conditions.

When considering the tonnage losses in the above experiments, it should be noted that any differences between treatments represent minimum differences, for had harvesting been delayed the effects would have become progressively worse as the season advanced. It has previously been pointed out that yield comparisons do not always adequately reflect the value of certain treatments unless they are

interpreted with other data. It is also misleading to judge the efficacy of a treatment solely on the basis of the number of live grubs revealed by diggings, since some grubs might not have contacted the band of insecticide whilst others might be immobilized and unable to injure the plant. For instance, in the second ratoon crop on Farm C, the May diggings revealed that, though a gradual and substantial reduction in grubs had occurred, there still remained a small but appreciable population which under normal circumstances would have been capable of inflicting visible damage. However, insofar as the 150 and 200 lb. treatments were concerned, it is considered that many of these grubs were immobilized, since no damage could be seen in these plots. The limited diggings carried out on Farm B appear to confirm these general conclusions. It seems, therefore, that the final decision regarding the efficacy or otherwise of a particular treatment must depend on whether or not plots so treated remain free from noticeable grub damage ; yield data and grub populations provide valuable supporting evidence.

Referring to results in the first ratoons during the 1948 season on Farms A and C (Tables 4 and 5), it can be seen that there was slight damage noticeable in both at the 100 lb. level of treatment, while in the second ratoon crop on Farm B in 1949 the 100 lb. and 125 lb. treatments proved inadequate. In the same year the 100 lb. treatment on Farm C, as well as showing substantial damage, also disclosed a small but significant tonnage loss when compared with the 150 lb. treatment. While some of this loss may have been due to the direct effect of grub attack during 1949, a portion at least of this was due to a reduction in vigour of the ratoons following some damage in these plots during 1948. Furthermore, a substantial proportion of the $7\frac{1}{2}$ tons difference shown in 1949 between the control and the 100 lb. treatment was due to a difference in ratooning potential following the severe damage sustained by these control plots in 1948.

The 125 lb. treatment on Farm A gave satisfactory protection over a period of two crops, while the 150 lb. treatment on Farms B and C gave complete protection throughout the three crops. No increased benefit was derived from dressings in excess of 150 lb.

Taken over the three crops, the 150 lb. treatment on Farm C showed a highly significant increase over the check plots each year, and in the aggregate this increment amounted to almost 20 tons. This figure is a conservative one for infestations of this severity, since the heaviest attack occurred at the end rather than at the commencement of the cropping cycle ; moreover, when the crops were badly damaged they were harvested during the early part of the crushing season. Nevertheless, the tonnage gain in the 150 lb. treatments represents a net return of approximately £45 per acre against an outlay not exceeding £7 10s. for material and costs of application.

It will be evident from the severity of the infestations on Farms A and C in 1948 and on Farm B in 1949 that, if weather conditions are favourable, heavy grub populations can build up quite rapidly in places where only light infestations were apparent in the previous year. Consequently, although no signs of grubs may be evident at planting time, growers in areas liable to damage cannot risk heavy infestations at some subsequent period within the crop cycle. Hence the treatment

rate should be adequate to provide sufficient residual toxicity to cope with even the heaviest of infestations throughout the growth of the second ratoon crop. The 150 lb. plant crop dressing fulfils this requirement.

Normally, most canegrowers in North Queensland follow a four-year rotation, and on the basis of the above results it is now possible to recommend a treatment rate of 150 lb. of 10% " Gammexane " dust per acre applied to the young plant crop as a band dressing along the rows. Similarly, in those districts where it is usual to grow only a plant and first ratoon crop, a single dressing of 125 lb. applied to the plant crop is recommended. These single treatments will ensure complete protection against grubs of the greyback bettle over the entire crop cycle, and they are recommended in preference to the 100 lb. treatment with subsequent " booster " dressings as required. The latter, of course, entail additional labour and expense.

Form of Dust

The first " Gammexane " dusts supplied were manufactured on a pyrophyllite base but, because of the tendency of this dust to " fly " and because of the scarcity of pyrophyllite at that time, a change-over to a rock phosphate-pyrophyllite base was soon made after experiments had shown that rock phosphate alone as a base could not be processed satisfactorily.

Present-day dusts therefore are mainly mixtures of benzene hexachloride, pyrophyllite and rock phosphate in varying proportions. Gypsum and kaolin have been tried as diluents, but up to the present they have not been used extensively under field conditions, though some companies are now offering benzene hexachloride dusts processed on one or other of these bases.

Throughout all of the experimental work reported previously, a 10% " Gammexane "-pyrophyllite dust was used in preference to a " Gammexane "-rock phosphate dust solely in order to eliminate any differences due to the fertilizer value of the rock phosphate, since this would have complicated the interpretation of results. From the agricultural viewpoint, however, this fertilizer value of the diluent is an advantage, and on that account preference is being shown for benzene hexachloride dusts containing a high percentage of rock phosphate rather than for those manufactured on some otherwise worthless diluent.

In the early experiments the 10% dust proved a suitable form in which to distribute evenly the relatively light dressings of " Gammexane " that were being tested, and growers subsequently used the same material in the larger scale control operations on their farms. When first quoted, the price of the 20% dust at 1s. 8d. per lb. was twice that of the 10% material, and with control measures then being carried out on a year-to-year basis there was little incentive at that time to change over to the 20% product, since its use would have involved difficulties in application and treatment costs would not have been lowered. However, the position regarding the use of these two preparations altered materially in 1949 when, in the first place, a larger single dressing was recommended for control on a three-crop basis and, in the second place, the 20% product became available at 1s. 2d. per lb. in comparison with the 10% material at 10d. per lb.

The 20% dust had already been used successfully for grub control, and in view of this substantial reduction in price it became obvious that treatment costs would be appreciably lowered by applying the equivalent dressing of 20% "Gammexane." At a treatment rate of 75 lb. of 20% dust per acre this represented an outlay not exceeding £4/12/- per acre over a period of three crops, and as a result this product is now supplanting the 10% dust in cane grub control except where small supplementary dressings are required after ratooning.

PRESENT COMMERCIAL APPLICATION

In 1945 and 1946 the small amount of "Gammexane" available was fully utilised in investigational work, and it was not until 1947 that it first became available on a commercial basis. By that time some striking results from a number of experimental trials had become known, and because of its ease of application, efficacy and cheapness, it was quickly adopted by Queensland canegrowers in marked preference to other methods of grub control. Although 120 tons of 10% dust were supplied in 1947, this quantity did not meet requirements. Appreciable grub damage in the following years so increased the demand that it was not until the end of 1949 that the industry's needs were fully satisfied. In that season approximately 900 tons of benzene hexachloride dusts were delivered to growers for the treatment of an estimated 20,000 acres.

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WHITE GRUB INTENSITY MAP
OF THE
MULGRAVE & BABINDA MILL AREAS
Light grub infestation shown
Medium " " "
Heavy " " "
Scale 2 Miles to an Inch
Drawn and Published at the Survey Office, Dept. of Public Lands, Brisbane. Sept. 1949
Printed at the Govt. Printing Office
GRAFTON
SOPHIA
GADGARRA
RUSSELL
BELLENDEN KER
BARLE FRERE EXTENDED GOLD FIELD
MULGRAVE GOLD FIELD
National Park
State Forest
Aboriginal Inhabitants
Reserve for Public Purposes
Timber Reserve
Tobias Spit
Palmer Point
Flirt Point
Constantine Pt
Woolanmarroo South
Bramston Pt
Fanning Town
Goldsborough
Gordonvale
Sawmill Point
Mirriwinni
Eubenangee Swamp
Pawnbilly
Babinda
Chickaboogalla
Mt Massie
Mt Harold
Mt Graham
Mt Fletcher
Chalmynia Mt
Twin Pinnacles
Bartle Frere (North Peak)
Bartle Frere (South Peak)
Walsh's Pyramid
Mt Peter
Mt Mac
Putts Mtn
Centre Pk
North Pk
South Pk
Bell Peaks
Grey Peaks
Isley Hills
Malbon Thompson Range
Bellenden Ker Range
Mulgrave River
Russell River
Graham River
Little Mulgrave River
Lake Newell
Clamshell Falls
White Falls
Camelia Falls
Boltan Boltan Falls
Chamaro Falls
Carabou Falls
Windin Falls
Bridal Veil Falls
Tarzali
Babinda
Woolanmarroo
Harvey Creek
Bellenden Ker
Goldsborough
Fisheries
Highway
R.675
R.785
R.310
R.226
R.755
R.227
R.821 National Park
R 700
R 310
R 59
R 236
R 885
R 228
R 4
MH 12
MT
Reserve
1048
1928
1918
1921
1905
1935
1949
2.677
2.855
2.738
2.888
2.1673
2.1675
4750Ft
5220Ft
3872Ft
5267Ft
5001Ft
4222Ft
4162Ft
3000Ft
2700Ft
2200Ft
1100Ft
3117
3317
3000
2000
1000
Att 2000

The Commercial Use of Dichloroethyl-Ether for the Control of Cheese Mites

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SUMMARY

Trials of various methods of application of dichloroethyl-ether for control of mites in cheese factory holding rooms and cool stores are described.

Mites directly exposed to "atomised" dichloroethyl-ether sprayed into the holding room were killed by a dosage rate of 1 lb. per 1,000 cu. ft. capacity. A second treatment was necessary after turning the cheeses. The rind of both waxed and unwaxed cheese was tainted for about three weeks.

Attempts at control of mites in cool stores by means of vaporization of the fumigant or spraying from a fixed spray line were unsuccessful.

Application by means of a hand "atomiser" proved effective in cool stores, giving a complete kill of mites and producing no lasting effect on flavour or rind.

INTRODUCTION

In recent years mite infestation has assumed importance in the holding rooms of cheese factories, in cool stores and in ships' holds. This is attributed to the longer period in which cheese was stored in Queensland factories and cool stores during the war years, due to irregularity in shipping time-tables, and to an increasing tendency to market locally a more matured cheese.

The species concerned are *Tyrophagus longior* Gerv. and *Tyrolichus casei* Ouds, dominant in factory holding rooms, and *Tyroglyphus farinae* De Geer, commonest in cool stores. The difference in species dominance appears to be related to temperature differences, holding rooms being maintained at generally higher temperatures than cool stores.

In efforts to control the mites without tainting the cheese, manufacturers have in the past tried various materials, including ammonia, sulphur dioxide and formalin; only limited success has been attained with these chemicals. Following the reported successful experimental use of dichloroethyl-ether against cheese mites in New Zealand, the Department of Agriculture and Stock co-operated with a cheese manufacturing association and cool store owners in testing this material under commercial conditions in Queensland.

FACTORY HOLDING ROOM EXPERIMENTS

Two holding rooms containing cheeses (waxed and unwaxed) were treated with dichloroethyl-ether. The cheeses were standing flat on wooden shelves and neither room was filled to its capacity.

Equipment and Technique

An atomising spray trigger gun with adjustable fine spray nozzle, known as an Engine Cleaning Gun (Figure 1), was fitted to the factory's compressed air system by means of 90 ft. of $\frac{3}{8}$ in. diameter pressure tubing. A regulating valve and pressure gauge were attached at the end of the compressed air line. The fumigant was carried in a pint-calibrated half-gallon clear glass bottle. Army gas masks No. 4 III 1940 and 1941 models fitted with $\frac{3}{4}$ in. diameter 5-ply steam rubber hose, which was later replaced by the standard cannisters, were worn by the operatives.

Figure 1.
Atomising Spray Trigger Gun Fitted to Factory Compressed Air Line.

The dosages were calculated on the basis of 1 lb. of dichloroethyl-ether per 1,000 cu. ft. of room space and the discharge rate was 1 pint (1½ lb.) per 5 minutes.

The atomised spray was so directed that all cheeses, as well as empty shelves, were enveloped in the spray mist (Figure 2). As far as possible, marked wetting of cheese surfaces with the fumigant was avoided.

Room A

This room had a capacity of 5,500 cu. ft. and held approximately 15,000 lb. of cheese, consisting of 200 mediums, 600 loaf, 100 picnics, and 100 midgets. Most were waxed, with some unwaxed freshly removed from the press. Heavy mite infestations occurred on the floors, the shelving and the cheese.

A total of 4 pints of the fumigant was atomised at a pressure of 44 lb. per sq. in., which was considerably below the intended and optimum pressure of 70 to 75 lb. per sq. in. The room temperature at spraying was 79° F. and the relative humidity 73 per cent. The room was closed immediately after treatment and was kept sealed for 24 hours before being opened and aired. There was appreciable leakage of fumigant from the closed room.

Figure 2.
Treating Cheese on Shelves in Factory Holding Room.

After airing, the cheese was turned and transferred to treated shelves so that the previously untreated surfaces were now exposed, and a second dosage of 4 pints was applied at a pressure of 70-75 lb. per sq. in. with the temperature at 73° F. and relative humidity at 69 per cent. The room was fairly tightly sealed for the ensuing 48 hours. Twenty of the treated cheeses (10 waxed loaf and 10 unwaxed loaf) were held in this room for two months for observation.

Room B

The second treated room had a capacity of 7,500 cu. ft. and held approximately 7,000 lb. of cheese. Altogether there were 200 separate cheeses in the room, consisting of loaf and medium size, with equal proportions of waxed and unwaxed. Heavy mite infestations, showing all stages of the life cycle, occurred throughout the room and on the stored cheese.

A total of 5 pints of fumigant was applied at a pressure of 70 lb. per sq. in. The temperature of the room when treated was 69° F., and the relative humidity 76 per cent. The room was closed immediately after the treatment was completed, and the air circulation system operated for 46 hours, after which the room was opened and aired for a few minutes before observations were made.

All cheeses were then inverted and transferred to treated shelving and a second treatment of 3½ pints applied at a pressure of 70-75 lb. per sq. in., the room temperature being 73° F. and the relative humidity 69 per cent. The room was closed for 48 hours after treatment. Observations were made on 28 of the treated cheeses (8 waxed medium, 10 waxed loaf and 10 unwaxed loaf) over a period of two months.

Subsidiary Trials

In view of the possible significance of the treatment in the trade, treated and untreated cheeses were crated and stored in a holding room heavily infested with mites. The treatments included (a) treated cheese, in untreated crate ; (b) treated cheese, in treated crate ; (c) untreated cheese, in treated crate ; and (d) untreated cheese. Each crate contained four 40 lb. cheeses, two waxed and two unwaxed. The treated cheeses were taken from Room B after the first fumigation and each therefore had one untreated surface. The treated crates had been sprayed thoroughly during treatment of the rooms and left for the 46 hours between the first and second treatments. Subsequent storage was for a period of two months.

In addition, one waxed and one unwaxed loaf cheese were each swabbed with dichloroethyl-ether, labelled, placed in the untreated cheese room, and examined periodically for odour retention. One waxed and one unwaxed cheese were retained in a saturated atmosphere of dichloroethyl-ether, the cheese being stored for a period of six weeks in a desiccator, with a petri dish containing the fumigant. Examinations were made as to any possible effect on the flavour of the cheese.

To check on the lethal effect on the total mite population, collections of dust scrapings, including eggs, nymphs and adults from shelves, floors and exposed cheese surfaces, were returned to the laboratory for examination. Small pieces of mite-free cheese were placed with each sample in sterile petri dishes and held up to a period of one month.

Results

Effect on Mite Infestation.

Immediately after the first treatment, samples taken from the floors, shelves and cheese surfaces were examined for living mites. The " kill " appeared to be complete at all stages of the life cycle where direct exposure to the effects of the

fumigant occurred. The treatment, however, had no effect on the mite population under the cheese, whether resting on the shelves or on other cheeses, or in cracked cheese where penetration of mites had occurred to a depth of up to 2 in. The surviving mite population, except in the cracked cheese, was, however, destroyed by the second application. Even in the cracked cheese there was a surprisingly high mortality of mites, though the percentage survival of mite population here was greater than was desirable.

The collections of dust scrapings when incubated with mite-free cheese in sterile petri dishes for one month gave no sign of further mite development.

Period of Immunity by Treatment.

Examination of the experimental cheese two months after treatment failed to reveal any mites apart from a few in Room B. There was furthermore no indication of rind taint or smell, or of taint of dichloroethyl-ether in the interior of the cheese.

However, two pockets of infestation were observed in Room A, suggesting that the lower pressure employed was less effective than the higher one used in Room B.

Continued observation of the treated rooms indicated that a second complete treatment was needed three months after the first treatment. With improved factory hygiene a considerably longer period of immunity could have been expected.

The two cheeses, one waxed and one unwaxed, swabbed with dichloroethyl-ether at the time of room treatment and stored for two months in the heavily infested third holding room, both became mite infested, but they were in much better condition than comparable untreated cheese. This suggests that the treatments had a residual effect. Neither the rind nor the interior of the cheese showed any effect of the treatment.

All of the crated cheese held in an infested room for two months carried a population of mites, but the treatments a, b and c showed a lower infestation than the check d ; in fact, only mild and localized infestation occurred in the three treatments mentioned. The low infestation of untreated cheese in a treated crate suggested that this might represent a practicable method of handling export cheese.

Effect on Flavour of Cheese.

Immediately following the first treatment, plugs from waxed and unwaxed cheese were examined, and were found to be free from taint. However, the rind of both waxed and unwaxed cheese had a distinct smell of dichloroethyl-ether. The odour in the rind, and in the rooms generally, persisted for about a week, but it gradually diminished in intensity. After three weeks, neither the odour in the rooms nor the rind taint could be detected with any degree of certainty. There appeared to be no physical effect of the fumigant on the rind of either waxed or unwaxed cheese.

Both the waxed and unwaxed cheese initially swabbed with dichloroethyl-ether retained a strong rind smell and taint, but there was no evident penetration into the interior of either. After a period of two months no treated cheese showed

any indication of dichloroethyl-ether taint in the rind. The rinds of two cheeses, one waxed and one unwaxed, examined after six weeks' storage in a saturated atmosphere of dichloroethyl-ether had a strong odour of the fumigant, but the interior was free from taint.

COOL STORE EXPERIMENTS

The experimental work at the cool store was concerned mainly with attempting to devise a more convenient method of applying dichloroethyl-ether than was adopted at the cheese factory, as well as to ascertain the effect of the treatments on large consignments of export cheese both in cool store and during transit overseas. The cool store room had a capacity of approximately 50,000 cu. ft.

The methods tried were (a) vaporization of the fumigant, buffered against explosion with carbon dioxide ; (b) spraying from a fixed spray line ; and (c) spraying from a hand " atomiser."

Dichloroethyl-ether as a Vapour

The apparatus used for the vapour treatment consisted of a drum container for the fumigant, a hot water tank fitted with a double-header constructed from 3 in. and $\frac{1}{2}$ in. piping, and a bank of six 50 lb. CO_2 cylinders linked together with a header. Compressed air at 200 lb. per sq. in. was also available. These were joined together into a system with $\frac{1}{2}$ in. piping, pressure taps and gauges, the outlets being distributed along a pipeline within the building. The drum to hold the fumigant and the hot water tank were each placed on a large electric hot plate. However, in spite of the amount of heating provided, this method of vaporizing the fumigant in sufficient quantity was unsuccessful and, even so, pipeline condensation took place.

Dichloroethyl-ether from a Fixed Spray Line

For this purpose the apparatus used in the vaporization trial was modified by the omission of the heating equipment and the CO_2 cylinders. The plain pipeline outlets were replaced by downwardly directed fine mist nozzles uniformly spaced, the line being suspended at a suitable height entering from the west end of the chamber. The fumigant was sprayed by means of the compressed air.

Eighteen paper trays, each approximately 18 in. square and 1 in. deep, were placed in various parts of the chamber and at different levels. Each tray contained approximately a level teaspoonful of living cheese mites and mite debris. Of each pair of trays, one was open and exposed, the other was covered to the extent that a piece of flat cardboard of equal size was supported above it on legs 6 in. high to intercept any downward falling spray.

The full dose of 1 lb. of fumigant per 1,000 cu. ft. of chamber space was given, but maximum pressure obtained in the airline was only 130 lb. per sq. in. This relatively low pressure, combined with some unsuitability of the nozzles for " atomisation " and the pressure gradient in the pipeline, resulted in poor distribution of the fumigant in the chamber.

Table 1, showing the results of examinations of the mite samples on the paper trays removed from the chamber after an exposure of 24 hours, indicates that, except in the case of three trays placed at the 4-crate level, what may be termed the mite-survival figure was satisfactorily low, compared with a control figure of 50.

Table 1

NUMBERS OF LIVING MITES FOUND IN SAMPLES OF MITES AND MITE DEBRIS DURING 8-MINUTE SEARCH PERIODS.

Part of Building	Level of Tray	Tray	
		Covered	Exposed
East end	On floor	0	0
	2-crate	6	5
	4-crate	20	17
Centre	On floor	0	0
	2-crate	1	6
	4-crate	0	18
West end	On floor	0	0
	2-crate	0	0
	4-crate	0	1
	TOTALS	27	47

Number of living mites found in one untreated sample during 8-minute search period : 50.

The mite survival figure at the east end was low because of the poor operation there of the nozzles, but it indicated that some general diffusion of the mist and vapour did take place, aided by the air-circulatory system of the chamber.

Dichloroethyl-ether from an "Atomiser"

An engine spray gun with an adjustable spray nozzle and a one-quart capacity cannister was attached by means of 60 ft. of $\frac{3}{8}$ in. diameter pressure tubing to a mobile compressed air tank with an air compressor operated by an electric motor. A pressure gauge and a regulating valve operating at 80 lb. per square inch were fitted. The general arrangement of this equipment is illustrated in Figure 3.

All outlets were carefully checked and sealed against possible gas leakage where deemed necessary.

As in the fixed line spraying experiment, trays containing samples of living mites were exposed in various parts of the room and at varying heights, some being protected and others unprotected from possible direct spray. As a simpler technique in checking mite survival, the outlines of mite accumulations were traced on the paper trays prior to the treatment.

The fumigant was applied as an atomised spray at the rate of 1 lb. per 1,000 cu. ft. and as uniformly as possible over crates, walls and towards the ceiling. Open floor spaces were also treated. The room was securely sealed for a period of 48 hours.

All of the sample trays examined after the room was opened showed a complete kill of mites. The cheese was examined by both Commonwealth and State graders,

who found neither the cheese flavour nor the rind to have been affected by the treatment.

Treated Cheese Consigned to U.K.

The contents of the rooms that had been treated by the fixed spray line and by the atomiser method were consigned in the one shipment to the United Kingdom, and examination in London by a qualified Commonwealth officer revealed the absence of mite infestation and of taint.

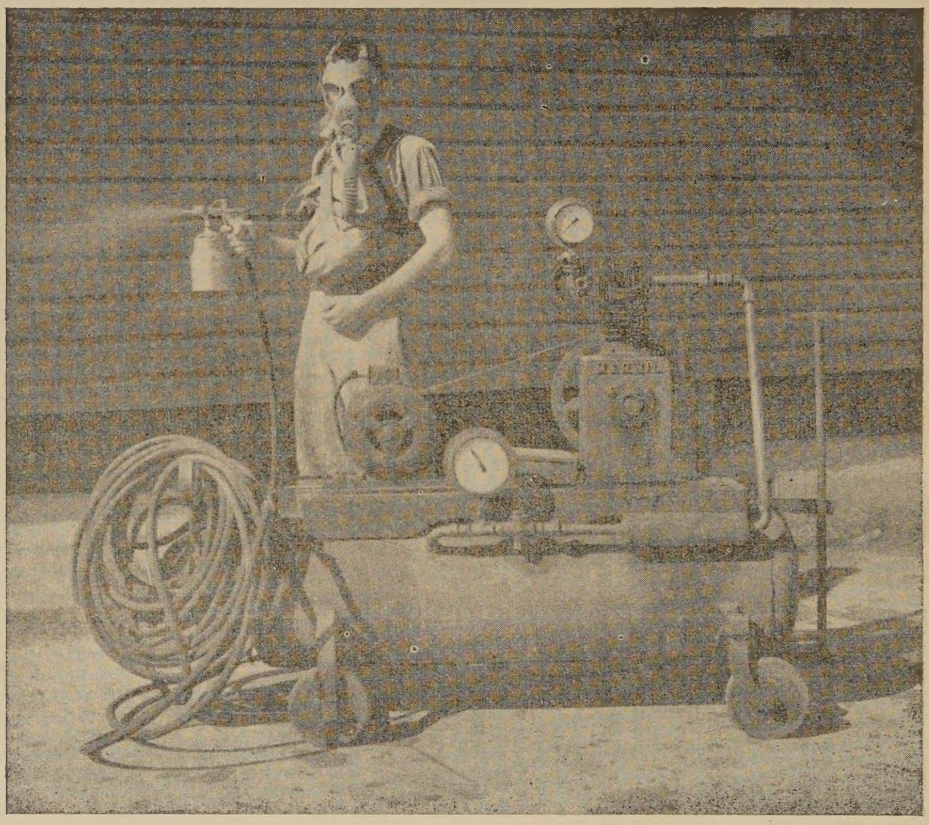

Figure 3.
Equipment used for Applying Fumigant to Cheese in Cool Store.

COSTS OF DICHLOROETHYL-ETHER TREATMENT

The costs of treatment at the cheese factory amounted to only a small fraction of a penny per lb., while at the cool stores the large quantity treated further reduced the costs. Dichloroethyl-ether is readily available and where improvised equipment cannot be used a complete portable outfit as illustrated in Figure 4 can be obtained at a reasonable price. Further large scale treatments carried out by the employees at six cheese factories and four cool stores have proved the " atomisation " method to be cheap, practicable and effective in controlling cheese mites.

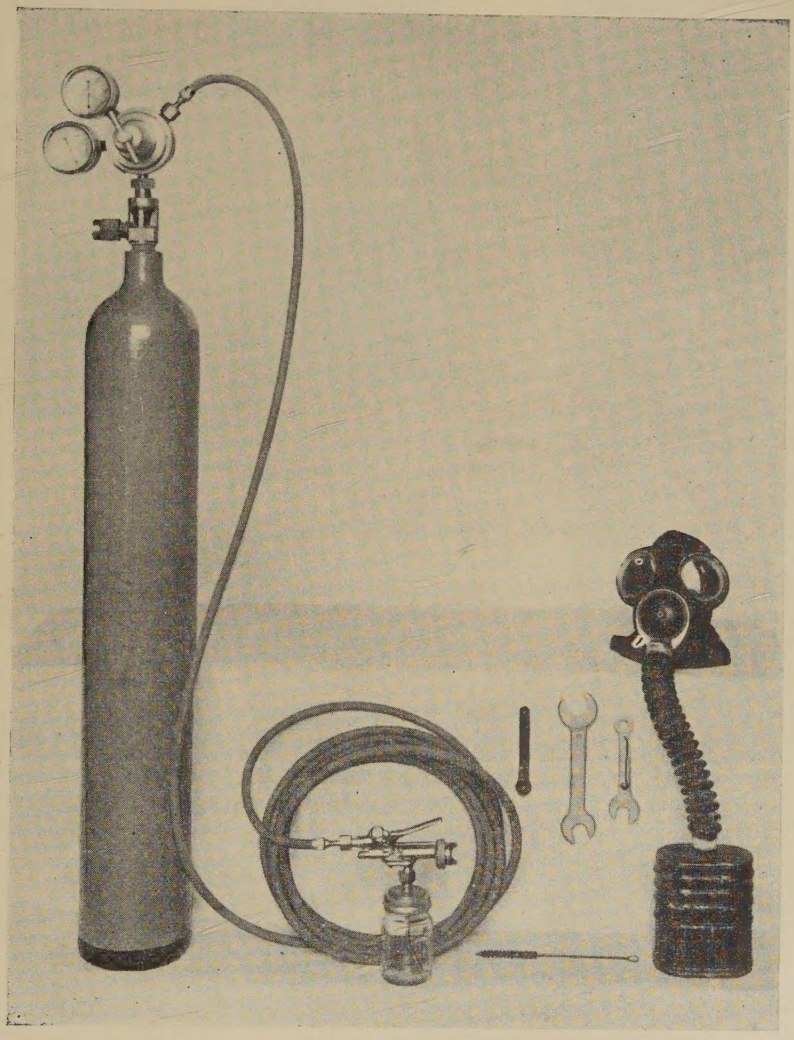

Figure 4.
Equipment Devised for Fumigating Cheese in Factory Holding Rooms.

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